Introducing "LISA"

LISA: Laboratory for Intelligent and Safe Automobiles

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Int. Workshop on
Progress and Future Directions of
Adaptive Driver Assistance Research

National Highway Traffic Safety Administration
Washington, DC
May 13, 2004

Presentation Outline

Research Scope

LISA Overview: Video Clip

Research Samples:

- Real-time Occupant Posture Analysis
- Driver View Estimation
- Driver Affect-State Analysis
- Vehicle Surround Capture
- Driver Behavior Analysis (Lane Change)
- Multitasking and Attention

Concluding Remarks

Research Scope

How to enhance Safe and "Efficient" Driving?

Multidisciplinary Focus on:

- Development of Complete Driving Context Capture System
- Robust Computational Algorithms for Context/Intent Analysis
- Detailed Behavioral Analysis of Driver and Driving Tasks
- Mental Models for Attention and Multitasking
- Multimodal Interfaces for Driver Attention Management

Video Clip

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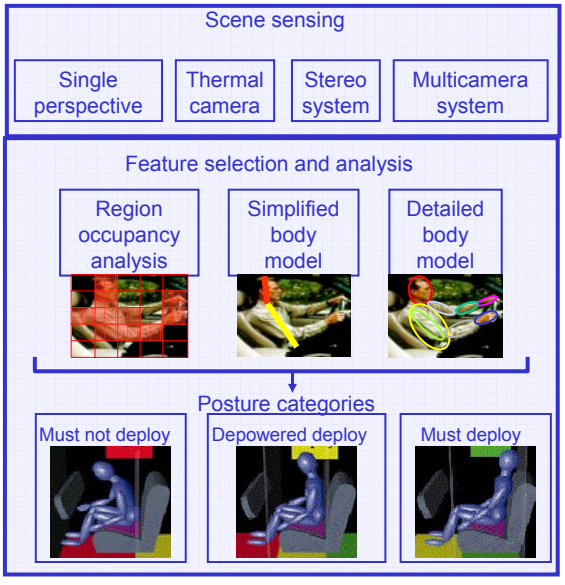
Vision Based "Smart Airbag" system



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Stereo, Voxel, &Thermal IR Video Streams Capture in LISA-P

M. M. Trivedi, S. Y. Cheng, E. M. C. Childers, S. J. Krotosky, "Occupant Posture Analysis with Stereo and Thermal Infrared Video: Algorithms and Experimental Evaluation", ***IEEE Trans. Vehicular Technology***, 2004

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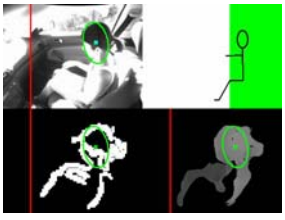
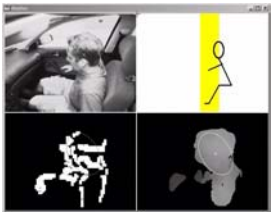
Real-Time Head Tracking





M. M. Trivedi, S. Y. Cheng, E. M. C. Childers, S. J. Krotosky, "Occupant Posture Analysis with Stereo and Thermal Infrared Video: Algorithms and Experimental Evaluation", *IEEE Trans. Vehicular Technology,* 2004,

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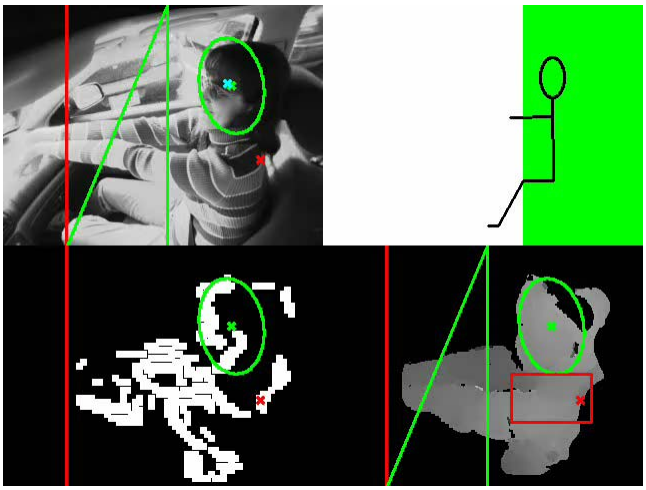
Stereo vs. Thermal IR

Occupant Task	Male 1, 5'8"		Female 1, 5'8"		Female 2, 5'11"		All Occupants	
	Stereo	LWIR	Stereo	LWIR	Stereo	LWIR	Stereo	LWIR
Sit Normal	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Lean Halfway	100.0%	73.0%	100.0%	92.9%	X	X	100.0%	82.8%
Lean Forward	76.4%	0.9%	X	X	X	X	76.4%	0.9%
Return to Normal 1	100.0%	95.9%	98.0%	98.0%	100.0%	100.0%	99.6%	97.4%
Lean Back	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Return to Normal 2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Lean Right	100.0%	52.1%	100.0%	100.0%	97.8%	96.7%	99.1%	92.1%
Lean Left	100.0%	98.9%	X	X	97.7%	100.0%	98.4%	99.7%
Return to Normal 3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Position Test Totals (Number of Frames)	**97.3% (940)**	**80.3% (776)**	**99.8% (537)**	**98.7% (531)**	**98.7% (676)**	**99.1% (679)**	**98.4% (2153)**	**91.7% (1986)**
Move Hands about cabin	78.1%	100.0%	100.0%	97.4%	97.8%	99.1%	91.6%	99.2%
Open the glove box	100.0%	100.0%	100.0%	95.5%	74.3%	97.6%	91.2%	97.8%
Put hands on face & stretch	81.7%	100.0%	100.0%	85.2%	87.8%	89.4%	90.0%	91.3%
Adjust car radio	100.0%	100.0%	100.0%	100.0%	99.4%	100.0%	99.8%	100.0%
Place hat in lap	100.0%	100.0%	100.0%	97.5%	100.0%	97.7%	100.0%	97.9%
Put hat on head	90.0%	84.3%	90.5%	35.7%	100.0%	93.3%	95.2%	85.2%
Move with hat	98.8%	87.9%	100.0%	68.3%	92.6%	62.8%	96.5%	71.0%
Remove Hat	100.0%	100.0%	100.0%	62.1%	100.0%	100.0%	100.0%	94.9%
Feet on Dashboard	100.0%	94.5%	100.0%	76.4%	93.9%	100.0%	98.3%	87.3%
Hand Motion & Object Test Totals (Number of Frames)	**92.6% (1399)**	**97.4% (1471)**	**99.8% (1939)**	**85.7% (1665)**	**92.0% (2258)**	**90.5% (2221)**	**94.8% (5596)**	**90.9% (5357)**
Free Motion Test (Number of Frames)	**100.0% (493)**	**87.4% (431)**	**99.8% (470)**	**95.5% (450)**	**95.8% (942)**	**86.1% (846)**	**97.9% (1905)**	**88.9% (1727)**
All Test Totals (Number of Frames)	**95.4% (2832)**	**90.2% (2678)**	**99.8% (2946)**	**89.6% (2646)**	**94.0% (3876)**	**90.9% (3746)**	**96.2% (9654)**	**90.3% (9070)**

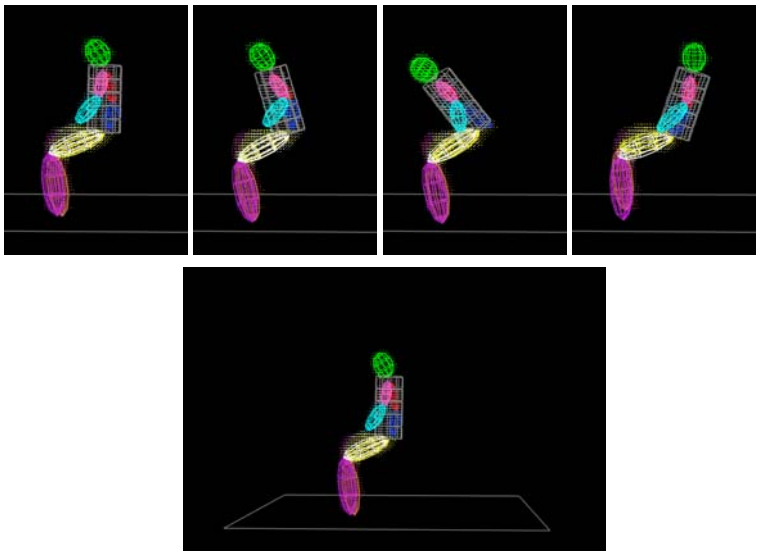
M. M. Trivedi, S. Y. Cheng, E. M. C. Childers, S. J. Krotosky, "Occupant Posture Analysis with Stereo and Thermal Infrared Video: Algorithms and Experimental Evaluation". ***IEEE Trans. Vehicular Technology***, 2004.

Tracking Body Parts and Objects



S. Krotosky and M. M. Trivedi, "Occupant Posture Analysis using Reflectance and Stereo Images for "Smart" Airbag Deployment" ***IEEE International Symposium on Intelligent Vehicles, Parma, Italy,*** **2004**

3-D Body Modeling and Tracking



S. Y. Cheng and M. M. Trivedi, "Human Posture Estimation Using Voxel Data for "Smart" Airbag Systems: Issues and Framework" *IEEE International Symposium on Intelligent Vehicles, Parma, Italy,* 2004
I. Mikic, M. Trivedi, E. Hunter, P. Cosman, "Human Body Model Acquisition and Tracking using Voxel Data," *International Journal of Computer Vision,* 199-223, July 2003.

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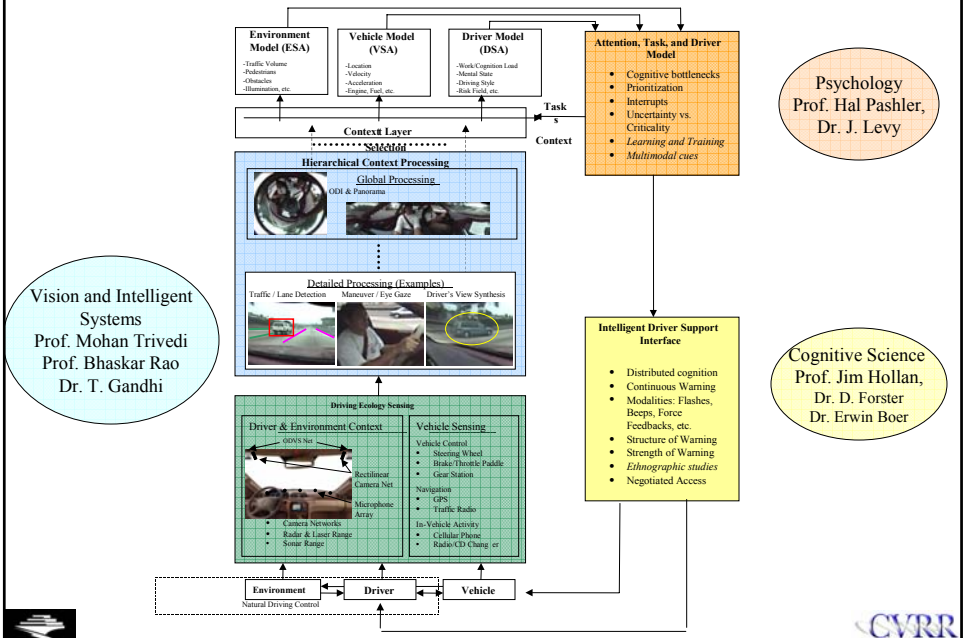
Human Centered Intelligent Driving Support System



Psychology
Prof. Hal Pashler,
Dr. J. Levy

Vision and Intelligent Systems
Prof. Mohan Trivedi
Prof. Bhaskar Rao
Dr. T. Gandhi

Cognitive Science
Prof. Jim Hollan,
Dr. D. Forster
Dr. Erwin Boer

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Driver Head-Pose and View Estimation with a single Omni-video Stream

Source omnidirectional video

Unwarped panoramic video

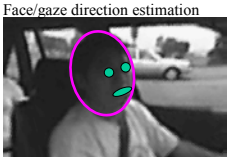
Unwarped perspective video on driver seat

Challenges:
- Drastic illumination changes, both on brightness and color.
- High frame rate (30fps) to capture detailed dynamics.

K. Huang, M. Trivedi, T. Gandhi, "Driver's View and Vehicle Surround Estimation using Omnidirectional Video Stream," *Proc. IEEE Intelligent Vehicles Symposium,* June 2003.

Driver's head detection/tracking

Face/gaze direction estimation



Relative angle to camera

Driver's view: 30° right

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Results: Occluded Face

Driver Seat

Head Detection

Head Tracking

Driver's Face

Estimated Driver's View

K. Huang, M. Trivedi, T. Gandhi, "Driver's View and Vehicle Surround Estimation using Omnidirectional Video Stream," *Proc. IEEE Intelligent Vehicles Symposium,* June 2003.

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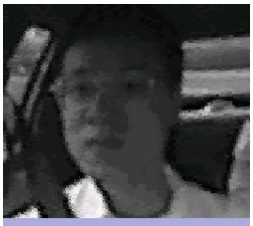
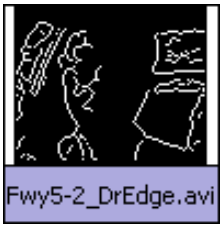
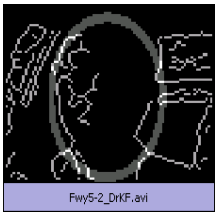
Head and Face Orientation Estimation





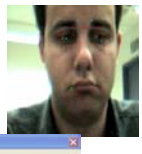


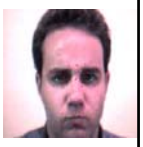
K. Huang, M. Trivedi, T. Gandhi, "Driver's View and Vehicle Surround Estimation using Omnidirectional Video Stream," *Proc. IEEE Intelligent Vehicles Symposium,* June 2003.

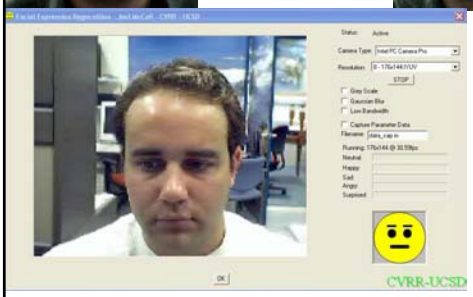
Driver Affect Analysis

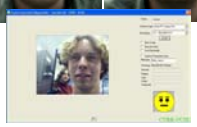
Initialization

Feature Tracking

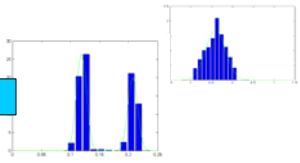








Feature Selection



Bayesian Estimation and Affect Classification

Eyebrow Distance

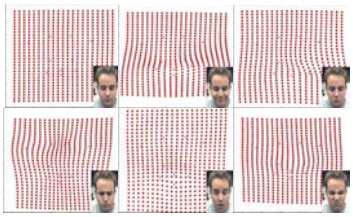
Mouth Curvature

J. McCall, S. Mallick, M. Trivedi, "Real-Time Driver Affect Analysis and Tele-viewing System," *Intelligent Vehicles Symposium, Proceedings. IEEE*, June 2003

Driver Affect

J. McCall and M. M. Trivedi, "Pose Invariant Affect Analysis using Thin-Plate Splines" *Proceedings of International Conference on Pattern Recognition 2004*

- Face Landmarks tracked in real-time
- Thin-plate spline warping separates rigid head motion from non-rigid face affect motion
- Warping parameter is classified into face affect or expressions



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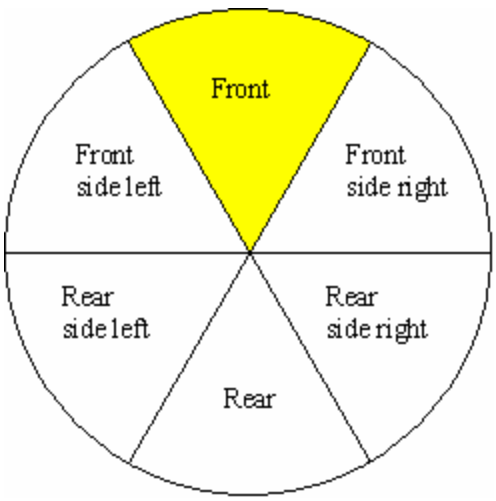
Full Surround Capture: an Integrated Approach



• T. Gandhi and M. M. Trivedi, "Motion Based Vehicle Surround Analysis Using Omni-Directional Camera," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004,

• O. Achler and M. M. Trivedi, "Vehicle Wheel Detector using 2D Filter Banks," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004,

• J. McCall and M. M. Trivedi, "An integrated, robust approach to lane marking detection and lane tracking," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004

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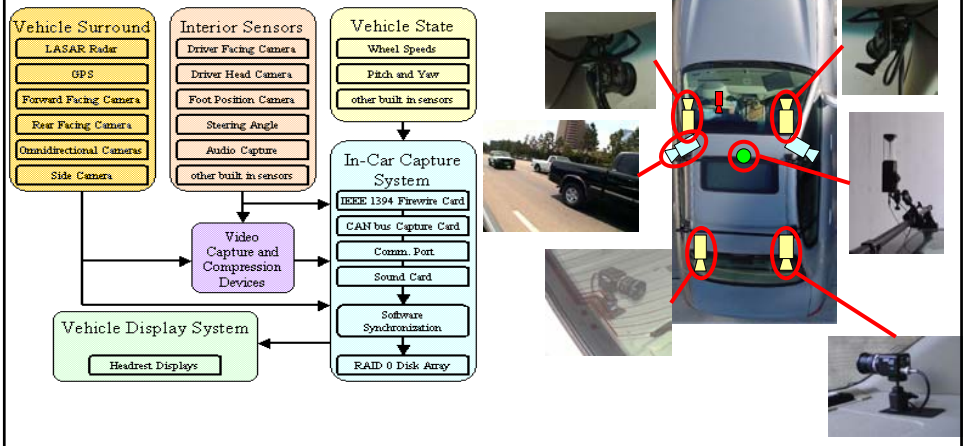
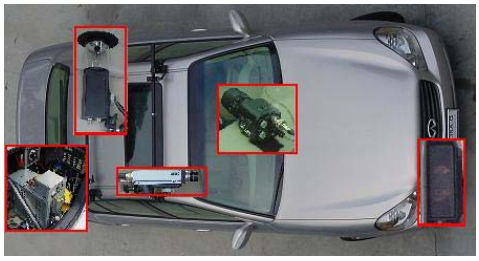
LISA-Q: A Novel Test-bed



J. McCall, O. Achler and M. M. Trivedi, "Design of an Instrumented Vehicle Testbed for Developing Human Centered Driver Support System," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004

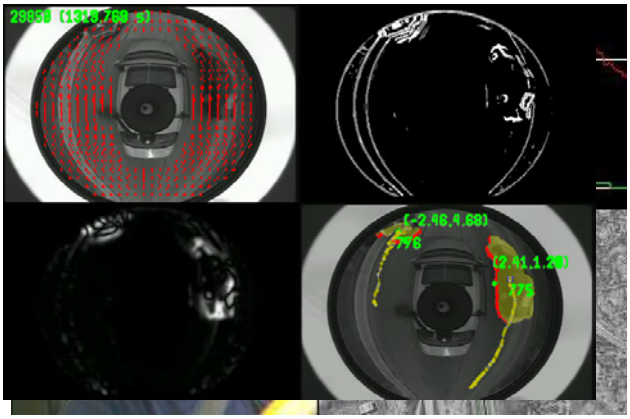
LISA-Q Test Bed

- Capable of extracting multiple modalities of sensor information for recording and/or processing
  - CAN Bus
    - Steering angle, pedal positions, vehicle speed, etc.
    - LASER RADAR distance to lead vehicle
  - 8 full frame video streams
    - Omnidirection cameras for 360 surround
    - Forward and rear facing rectilinear cameras
    - Rectilinear camera facing driver
    - Near-IR camera facing feet and pedals
    - Rectilinear camera mounted on headband for drivers view
  - GPS data
  - PC in trunk for data collection/processing



J. McCall, O. Achler and M. M. Trivedi, "Design of an Instrumented Vehicle Testbed for Developing Human Centered Driver Support System," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004

Context Capture



T. Gandhi and M. M. Trivedi, "Motion Based Vehicle Surround Analysis Using Omni-Directional Camera," *Proc. IEEE Intelligent Vehicles Symposium,* June 2004

Sensor Fusion for Context Capture

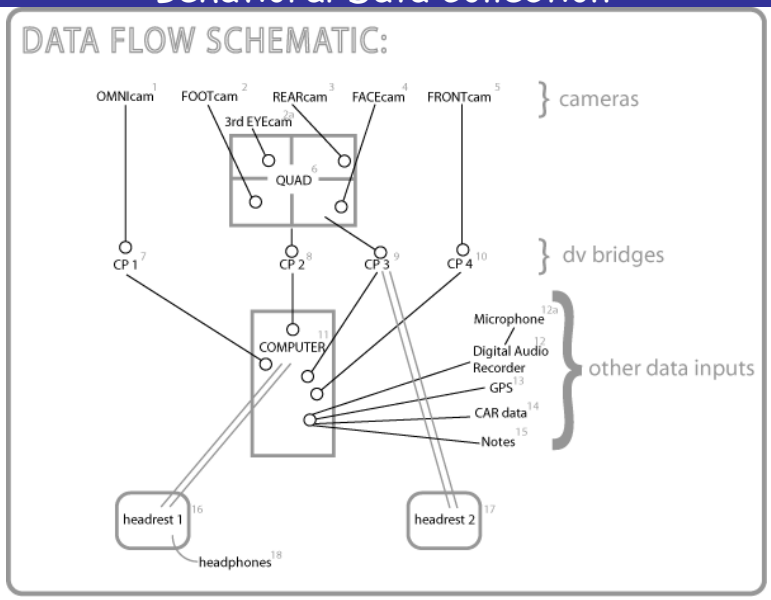
Ethnographic analysis

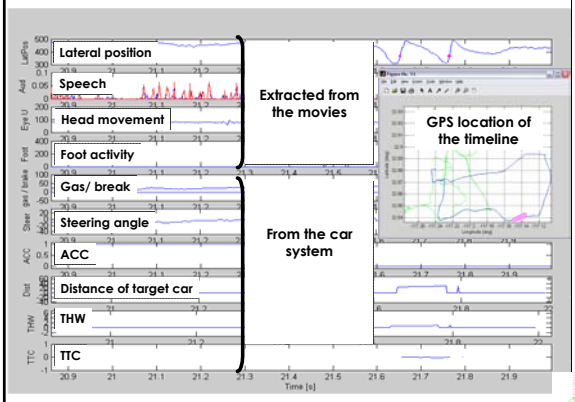
- Study natural situations of activity
- Confront heterogeneous data:
  - environment,
  - Driver's behavior
  - Driver's verbalization during action and after
  - Questionnaire,…
- Determine what is going on with the people
- Characterize meaning and expectation

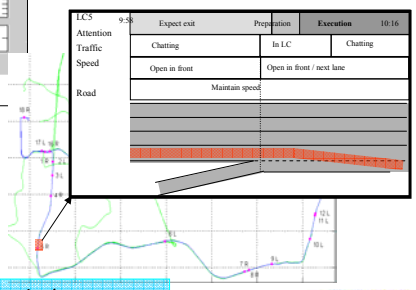
Behavioral patterns

- Automatic detection from system/movies
  - Cheaper in time and effort
  - Allows analysis and comparison on large scale
  - Open possibilities of detection by the system
- Give traces of driver's activity/context
  - Lane position => trajectory management
  - Head movement => control on traffic and road
  - Foot activity on gas/break => Speed management
- Find patterns to:
  - test similarities/differences between drivers/situation
  - predict the driver's situation ?

Behavioral Data Collection

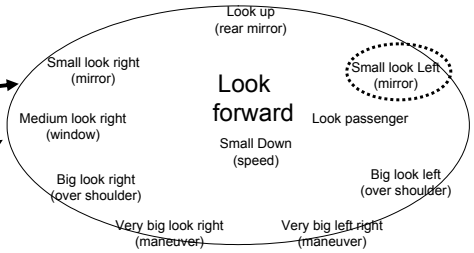


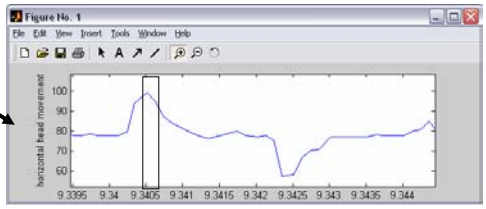




Head and Gaze Movement Categories

Ethnographic categories

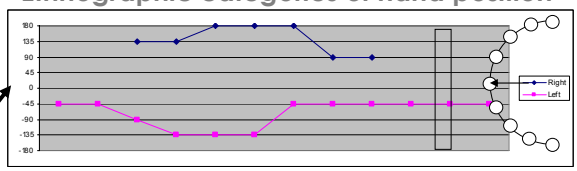


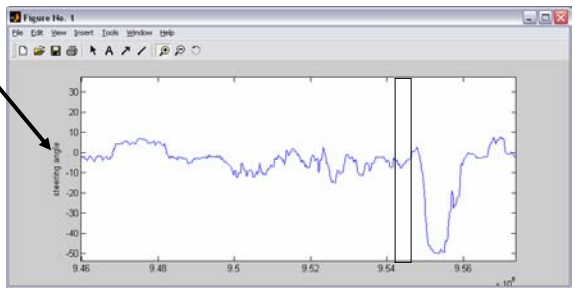


Automatic detection

Wheel and hand position

Ethnographic categories of hand position



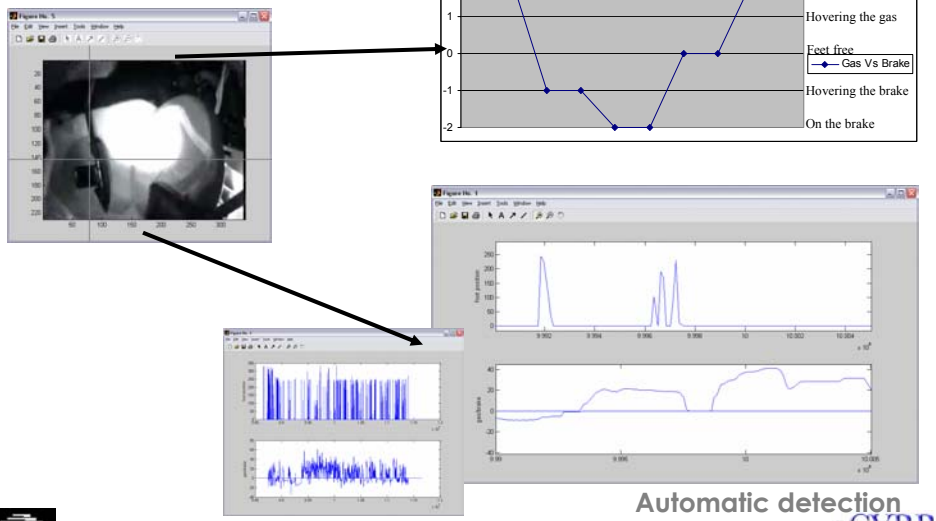


Problematic for Automatic Coding:
NO HANDS VISIBLE

System measure of steering angle

Foot position

Ethnographic categories of foot position



Automatic detection

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Speech detection

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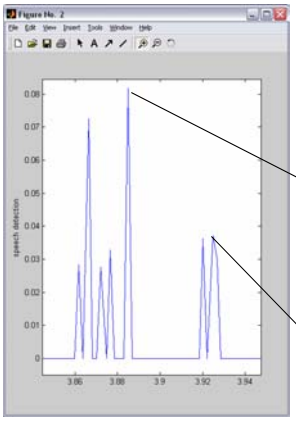
Automatic detection of moment of speech



janice_speak_JB.xls

	B	C	E	F	G	H	I
1	Noise Lev	Min	Sec	Speech	Discussion thread	Topic	Transcription
1791	0	3	51	0			
1792	0	3	51	0			
1793	0	3	51	0			
1794	0.02835	3	51	1	Directions	General direction	Ethnographer: so do you remember roughly where going?
1795	0	3	51	0	Directions	General direction	Ethnographer: so do you remember roughly where going?
1796	0.0725	3	51	1	Directions	General direction	Ethnographer: so do you remember roughly where going?
1797	0	3	52	0	Directions	General direction	Ethnographer: so do you remember roughly where going?
1798	0	3	52	0	Directions	General direction	Ethnographer: so do you remember roughly where going?
1799	0.02772	3	52	1	Directions	General direction	Ethnographer: so do you remember roughly where going?
1800	0	3	52	0	Directions	General direction	Ethnographer: so do you remember roughly where going?
1801	0.03284	3	52	1	Directions	General direction	Ethnographer: so do you remember roughly where going?
1802	0	3	52	0	Directions	General direction	Ethnographer: so do you remember roughly where going?
1803	0	3	52	0	Directions	General direction	
1804	0	3	52	0	Directions	General direction	
1805	0.08177	3	53	1	Directions	General direction	Driver: Yeah
1806	0	3	53	0			
1807	0	3	53	0			
1808	0	3	53	0			
1809	0	3	53	0			
1810	0	3	53	0			
1811	0	3	53	0			
1812	0	3	53	0			
1813	0	3	54	0			
1814	0	3	54	0			
1815	0	3	54	0			
1816	0	3	54	0			
1817	0	3	54	0			
1818	0	3	54	0			
1819	0	3	54	0			
1820	0	3	54	0			
1821	0	3	55	0			
1822	0.03637	3	55	1	Here and now	Getting familiar	Driver: Woah! This is a big car
1823	0	3	55	0	Here and now	Getting familiar	Driver: Woah! This is a big car
1824	0.03729	3	55	1	Here and now	Getting familiar	Driver: Woah! This is a big car
1825	0.02999	3	55	1	Here and now	Getting familiar	Driver: Woah! This is a big car
1826	0	3	55	0			

Use of speech detection for transcription and coding

Lane Changing1

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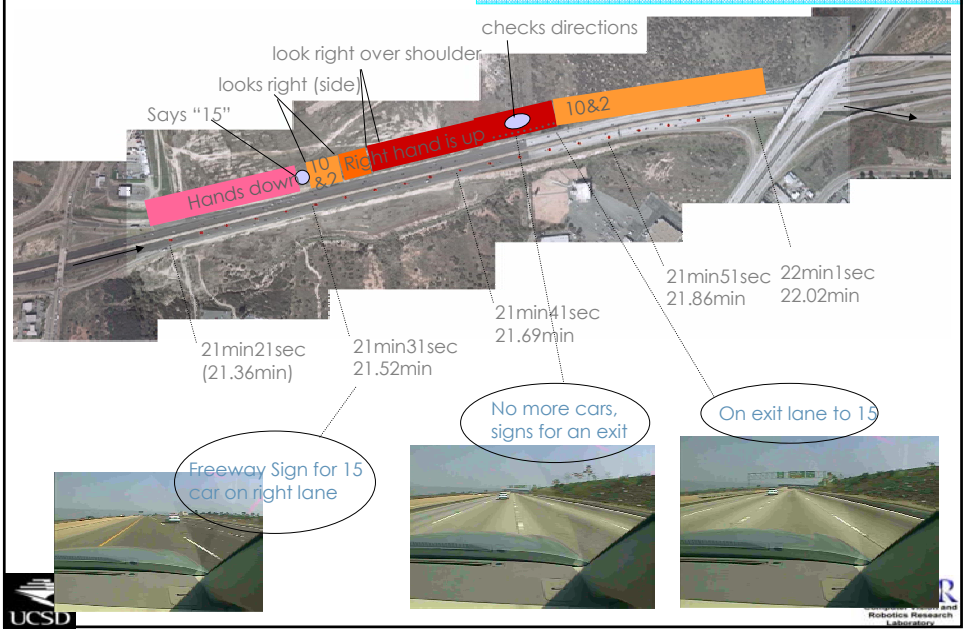
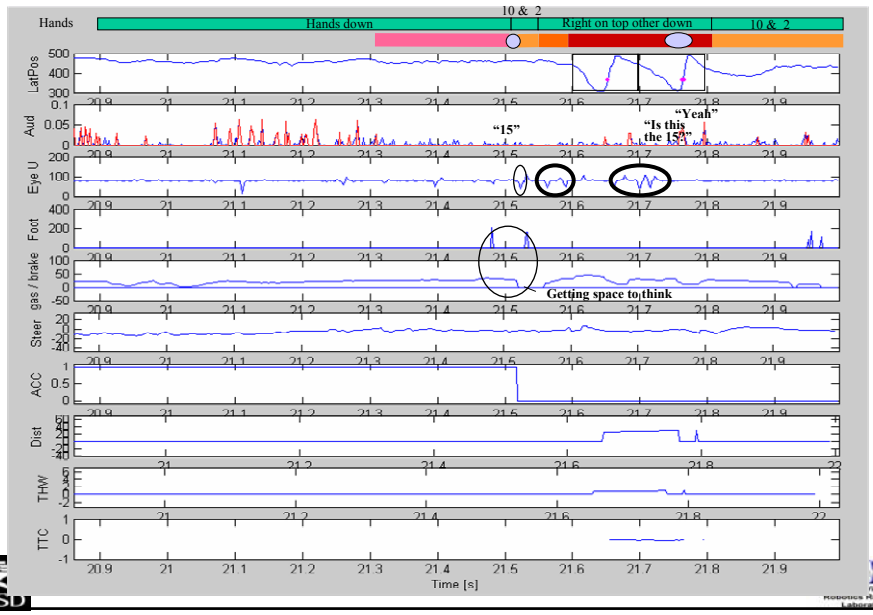


Lane Changing1

Human Computer Interaction Laboratory



Observations: steps of LC

1. Awareness of instability, caused by:
   - LC1: Road, do not want to miss exit
   - LC2: Traffic, passing a truck
   - Change in preparation state : an intent is formed
     - LC1: During sequence,
     - LC2: Before sequence, when get blocked by truck
2. Physical preparation: get ready for action
   - placing hands
   - checking conditions (spot in lane)
   - changing speed to get the spot (in LC2 only)
3. Execution:
   - Checking if no car coming
   - Acceleration
   - Stabilization of the trajectory / checking car in new lane

Concluding Remarks

- HC-IDSS brings disciplines closer
- HC-IDSS will continue to challenging research community
- Current Efforts are focused on
  - Automatic Context Extraction
  - Intent Analysis
  - Multimodal (Audio, Visual, Haptic) Interfaces
  - Integrated System Evaluation

Thanks !!

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